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**Zierolf**

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(54) **METHOD AND APPARATUS FOR DETERMINING POSITION IN A PIPE**

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( * ) Notice: This patent issued on a continued prosecution application filed under 37 CFR 1.53(d), and is subject to the twenty year patent term provisions of 35 U.S.C. 154(a)(2).

Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/286,650**

(22) Filed: **Apr. 6, 1999**

**Related U.S. Application Data**

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(51) **Int. Cl.**[7] .................................................. **G01V 3/00**

(52) **U.S. Cl.** .................................. **340/854.8**; 340/825.72; 340/572.7; 340/539; 166/254.2; 166/255.1; 705/65; 342/42

(58) **Field of Search** .............................. 166/254.2, 255.1; 340/10.42, 825.72, 572.1, 572.2, 853.8, 854.1, 854.6, 854.8, 539, 572.7; 705/65; 342/42

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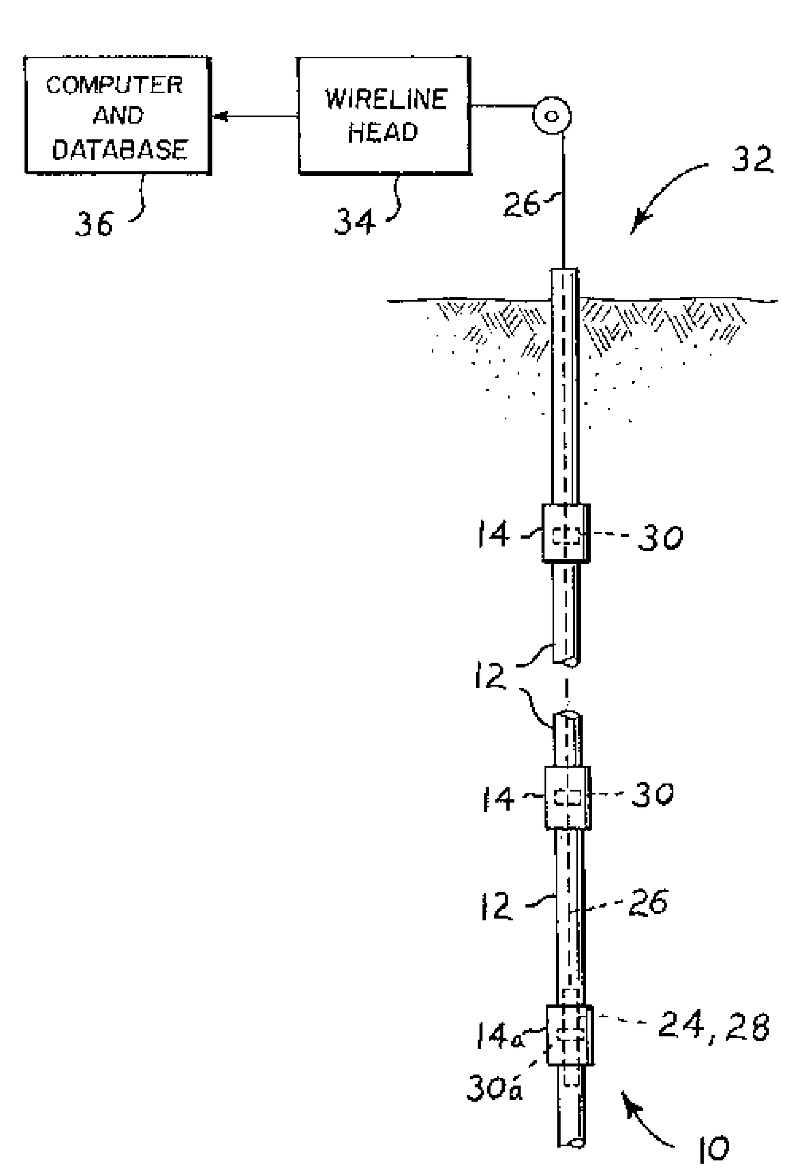
(57) **ABSTRACT**

A method and apparatus for determining position in a pipe provides for the precise determination of location and associated characteristics of each pipe joint of a well, cross country pipeline or other fluid transmission line. The system includes a passive or active radio identification device at each joint in the pipe or casing string. The devices are preferably sealed within the resilient seal positioned between each pipe or casing joint. A pipeline tool includes a radio transmitter and receiver, with the transmitter transmitting on a frequency selected for resonating the identification devices. The resonant response of each device is detected by a receiver in the pipeline tool, with the response transmitted to the surface via the wireline to which the tool is connected. Alternatively, the tool may include storage information means until the tool can be recovered from the well or pipe. An information storage and retrieval system includes information on the location of each of the identification devices in the well or pipe, e.g., length or depth, pipe or casing diameter, previously logged geological characteristics and stratum at each identification device location, etc. The system may count each device as the tool passes through the pipe in order to determine the location of the tool at any point. Alternatively, each identification device may provide a distinct signal, with the tool transmitting the signal to the surface (or storing the signal for later retrieval) where the system correlates the signal with previously logged information for that specific location.

**45 Claims, 4 Drawing Sheets**



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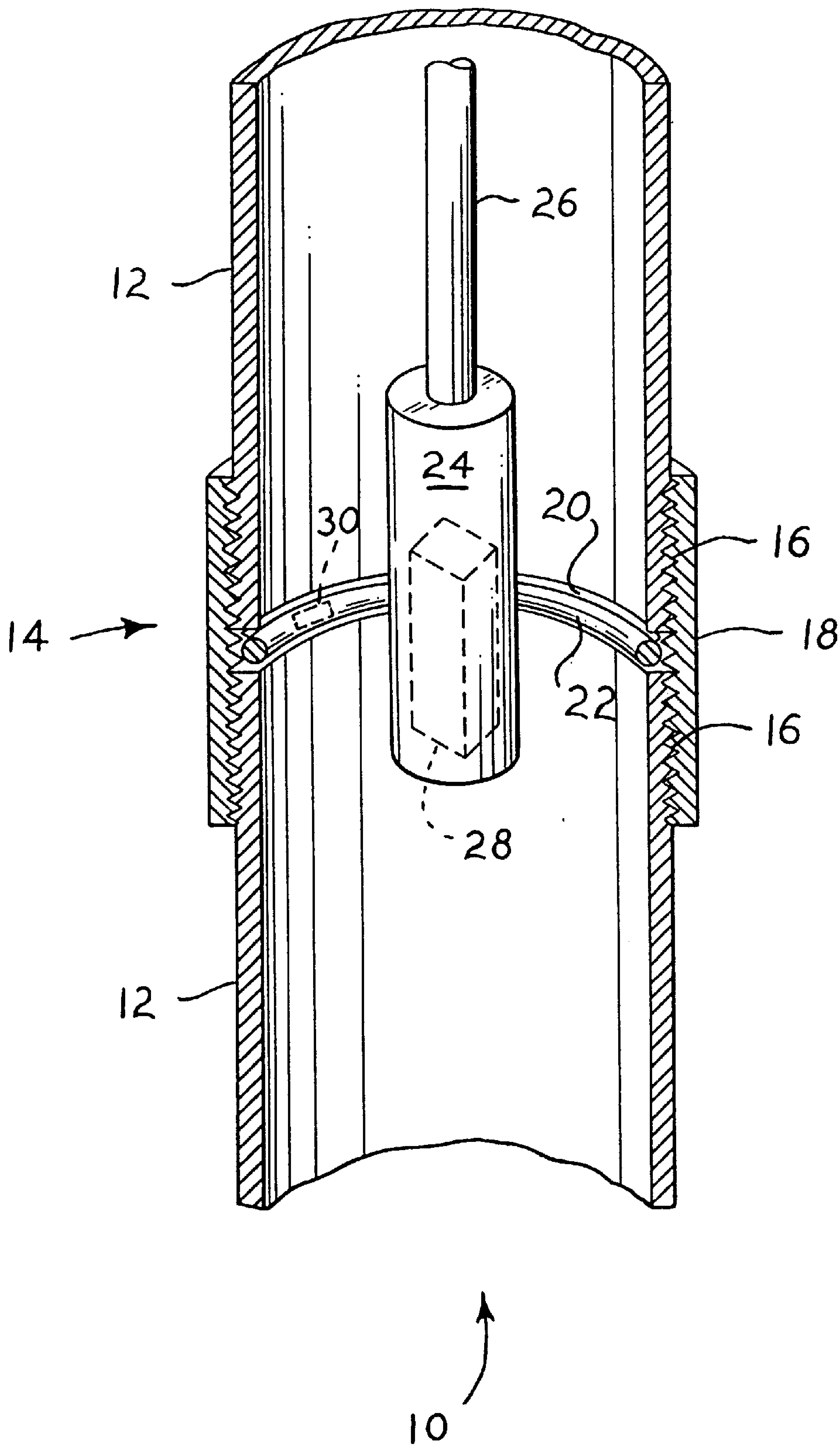
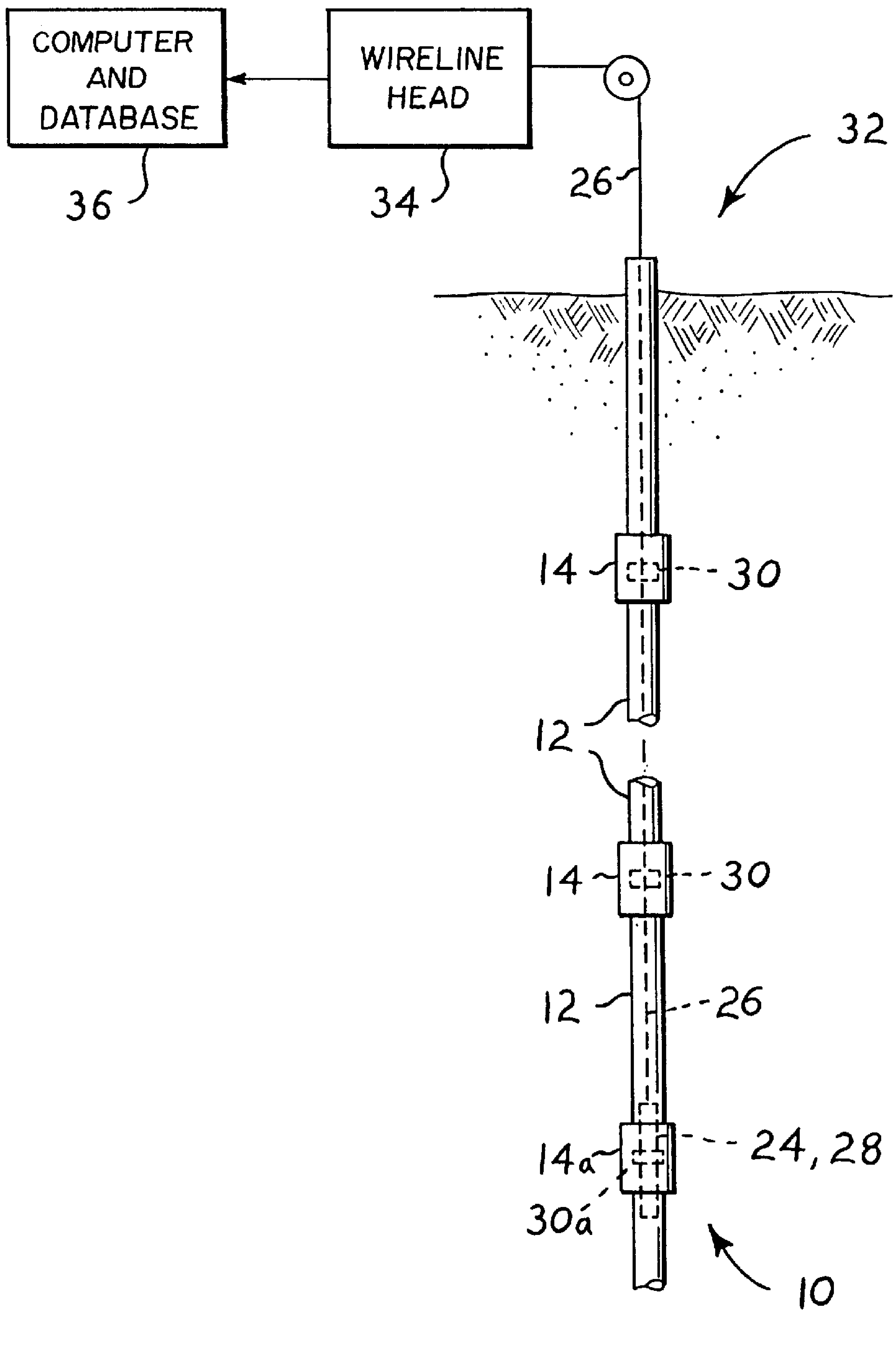



FIG. 1


COMPUTER AND DATABASE
WIRELINE HEAD
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14a
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30a
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FIG. 2

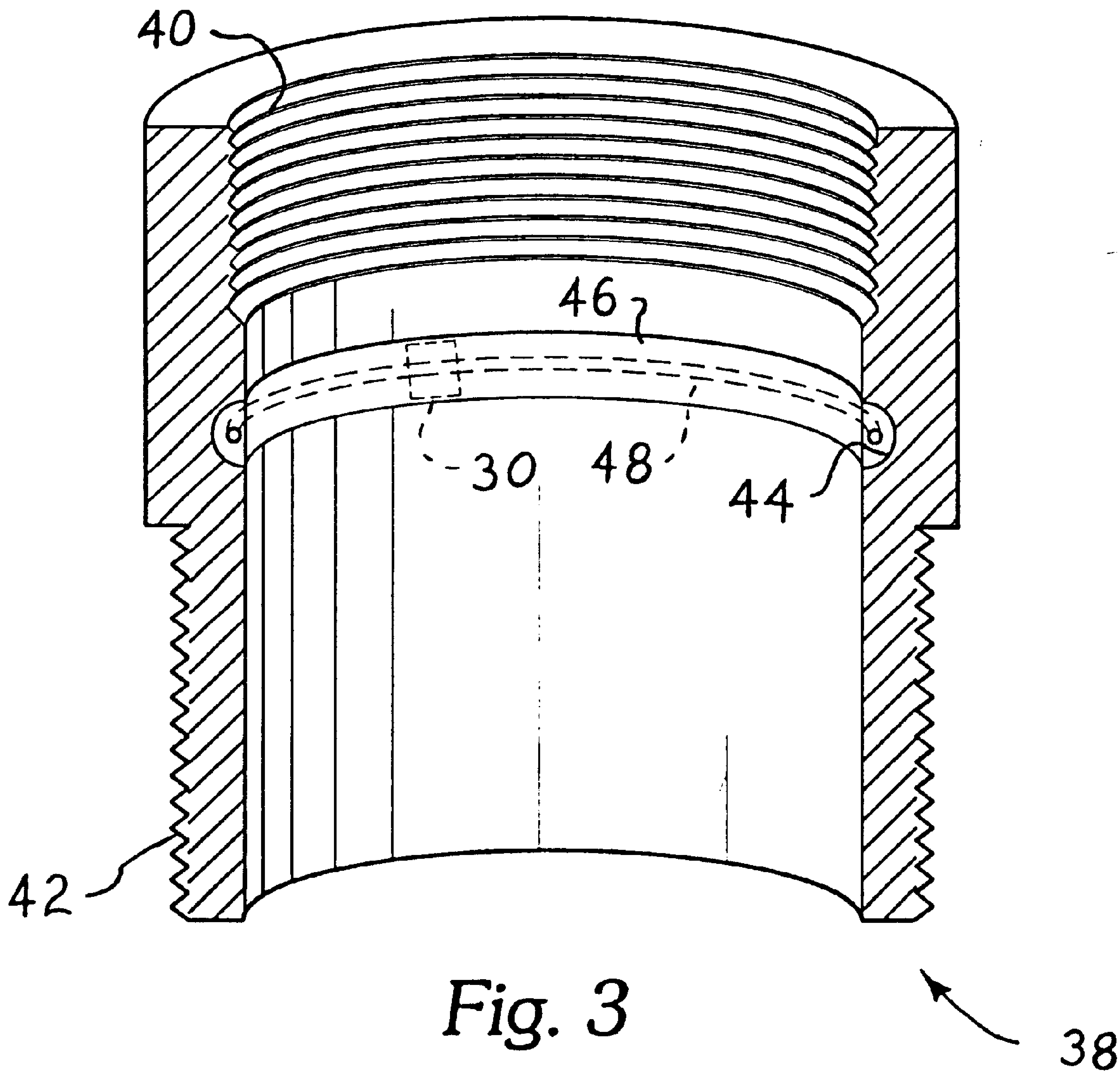


Fig. 3

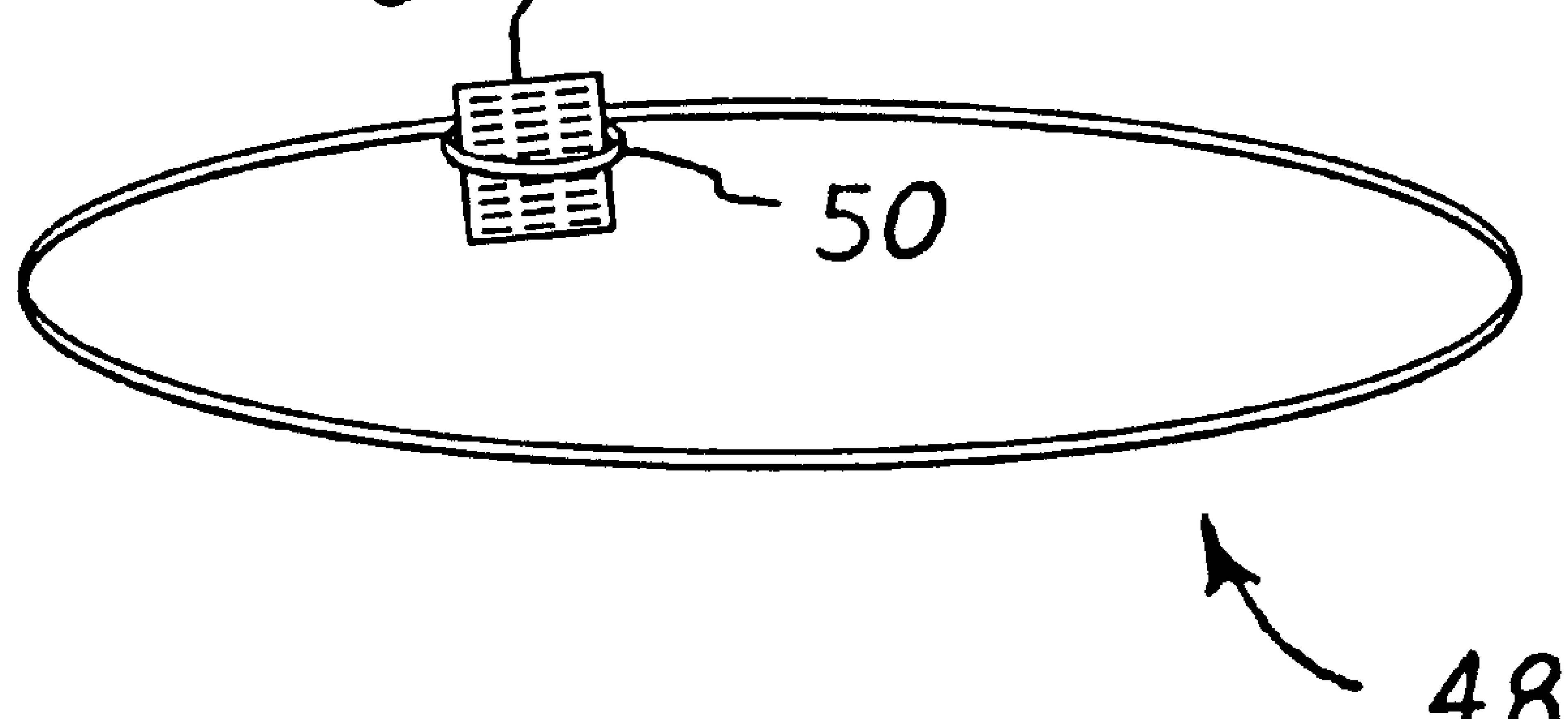


Fig. 4

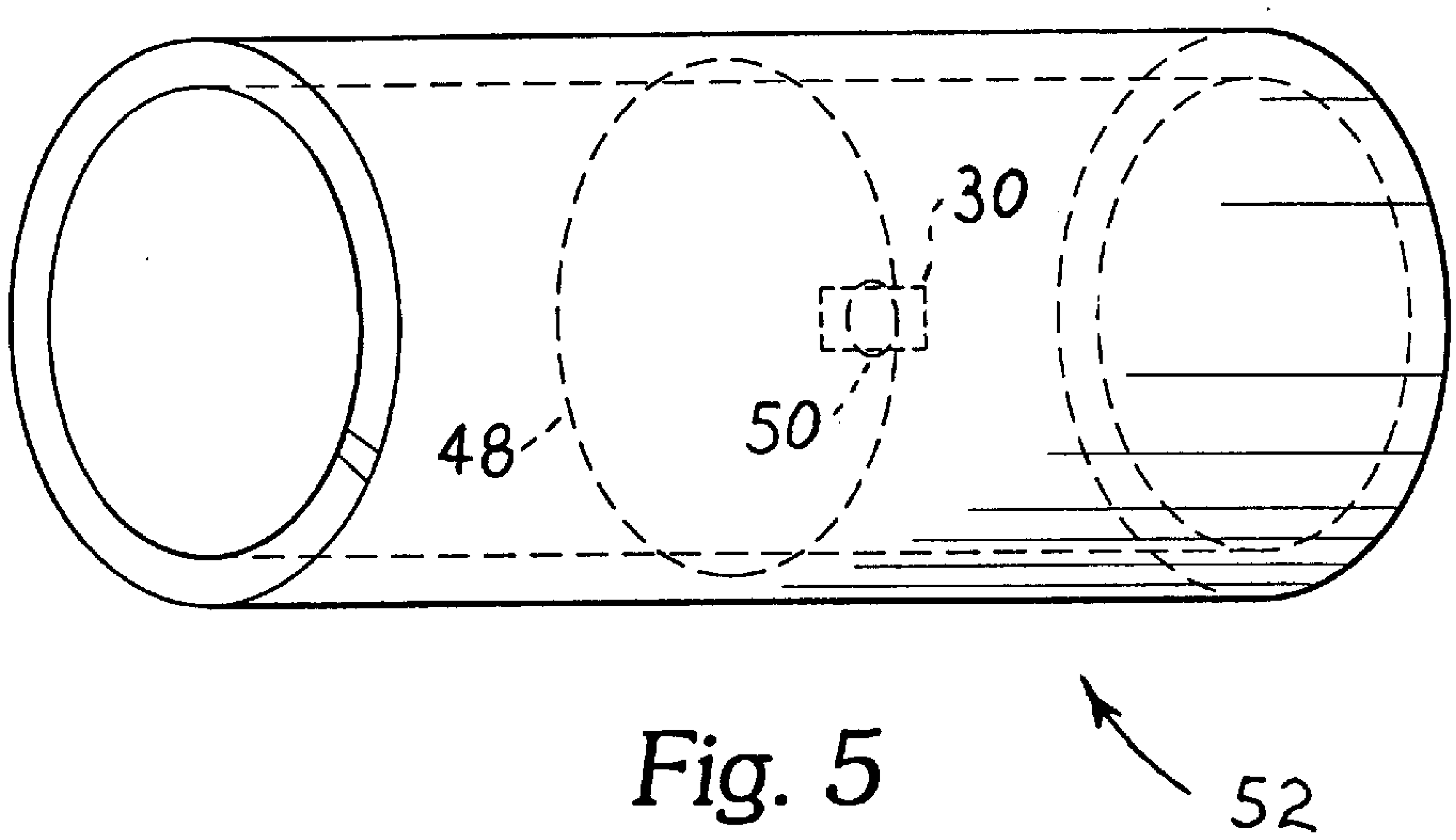


Fig. 5

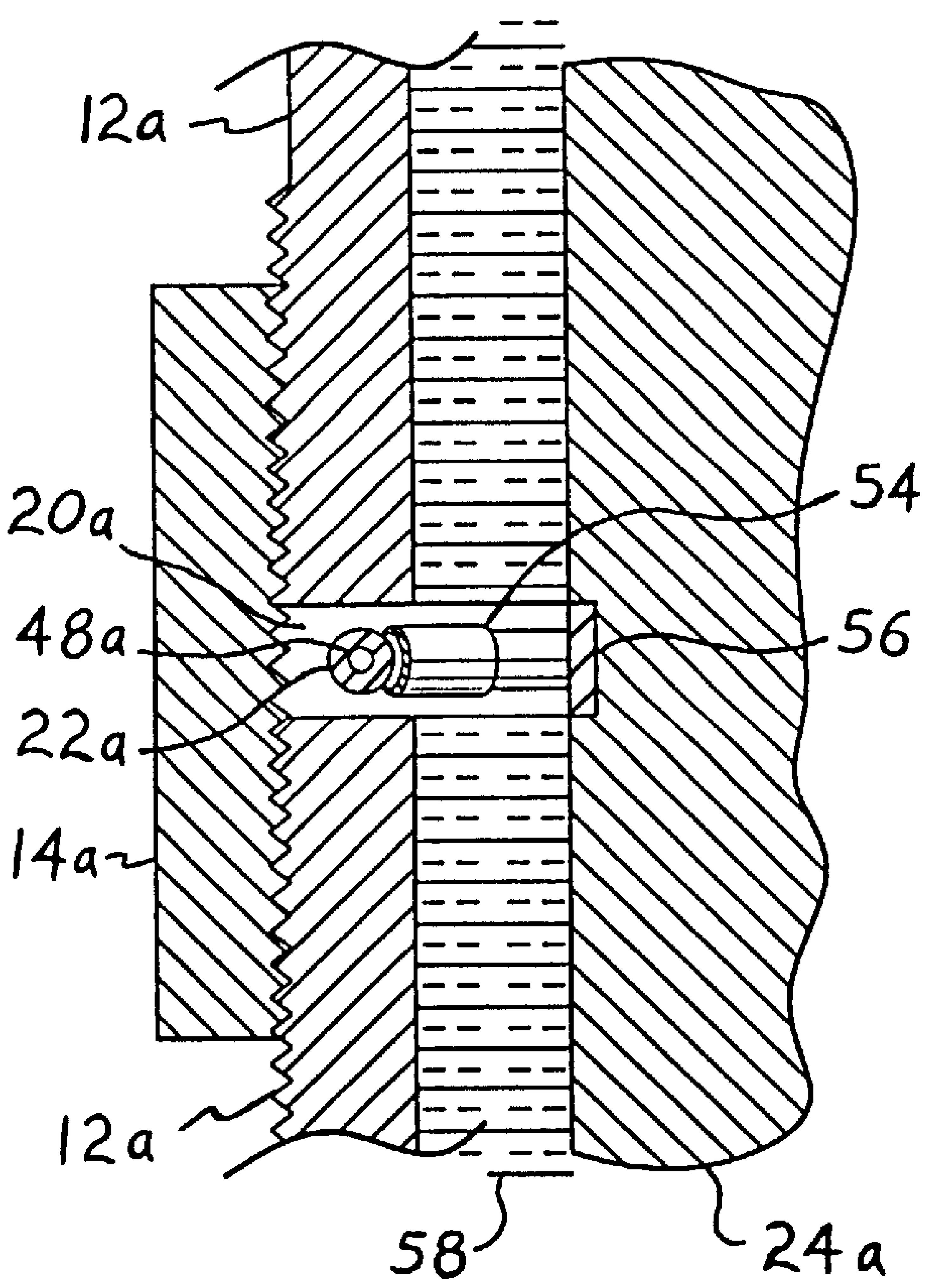


Fig. 6

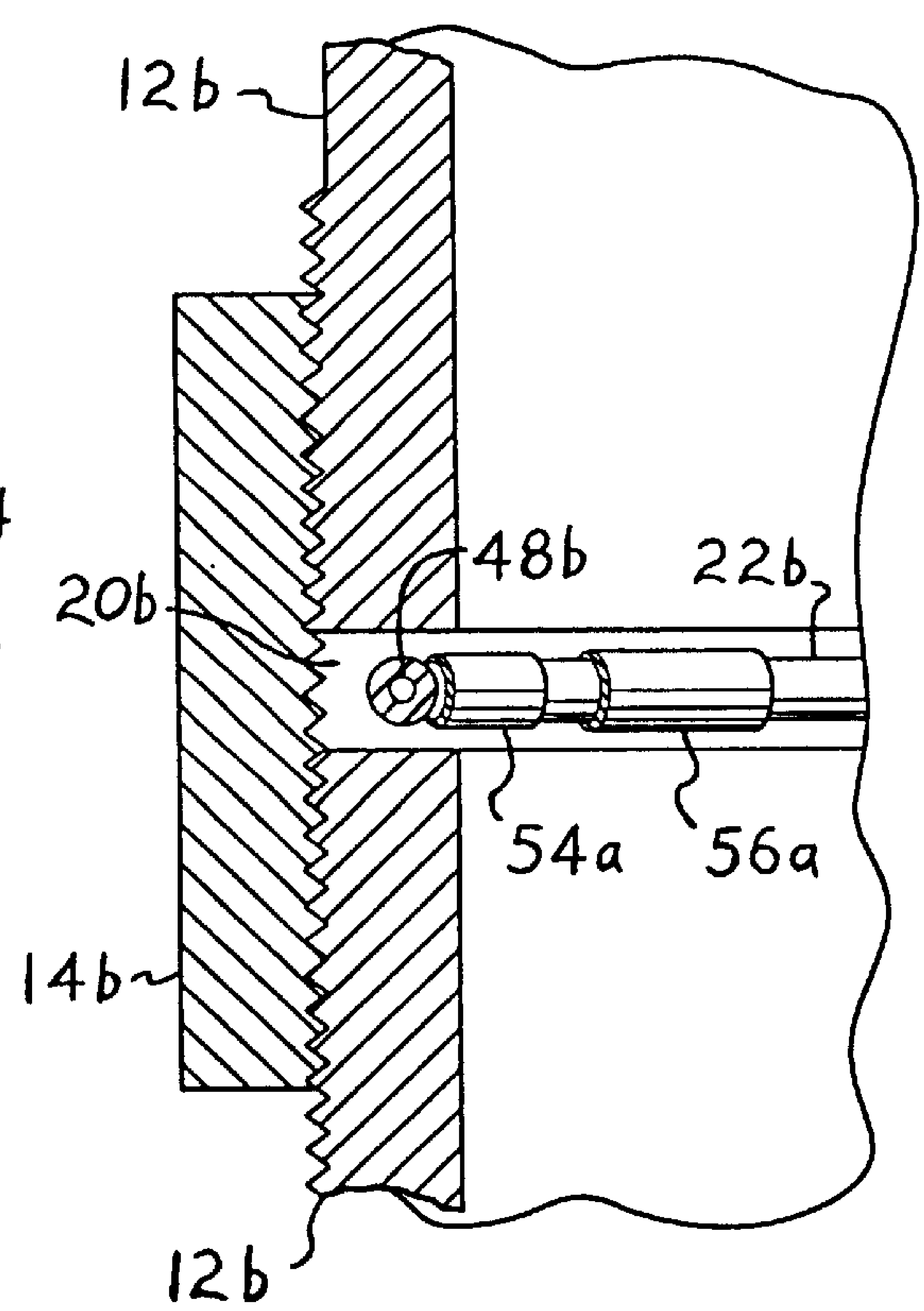


Fig. 7

# METHOD AND APPARATUS FOR DETERMINING POSITION IN A PIPE

## REFERENCE TO RELATED PATENT APPLICATION

This application claims the benefit of U.S. Provisional Patent Application Ser. No. 60/098,284, filed on Aug. 28, 1998.

## BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to devices for detecting intermediate points within wells, gas and oil pipelines, and the like, and more specifically to a system using radio frequency resonant devices installed at various points in the well or pipe. A detector is inserted into the pipe, and detects the resonant devices where installed to transmit location or depth and other information back to a station at the surface or along the pipe. The present invention may provide for the storage of the information gathered for downloading upon retrieval of the device from the well or pipe.

2. Description of the Related Art

The need for accurate measurement of the depth of a drilled well is critical, as oftentimes the stratum of interest in the well, resides within a relatively narrow band. Wells are typically cased after drilling, with cement being poured between the casing and the wall of the drilled hole in order to seal and stabilize the hole. The casing and cement are perforated at the desired depth in order to access the stratum of interest (oil bearing deposits, gas, water, etc.), with the casing and cement serving to prevent the flow and mixing of undesired fluids with the fluid of interest from the well (e.g., water with oil, etc.).

In view of the above, it is critical that the well be perforated at precisely the proper depth in order to avoid drawing an undesirable fluid into the well, and/or missing the desired stratum of interest in the well. As wells typically extend from a few to several thousand feet below the surface in the case of oil and gas wells, the precise measurement of the depth of the well to within a few feet, poses a difficult problem. U.S. Pat. No. 5,279,366 provides an excellent and detailed discussion of the problem in the Background of the Invention, columns 1 through 4, for further background.

Accordingly, numerous devices and systems have been developed in the past for logging or measuring the precise depth of the well, for perforating the well or for other purposes as required. Such principles as MRI (magnetic resonance imaging), gamma ray detection, and others, have been utilized in order to enable a detector lowered into the well casing to determine its position or depth within the hole. However, none of the systems or principles utilized in the past, provide the needed accuracy to enable an operator to determine precisely the depth of the tool within the hole. It is very easy for the well to be logged incorrectly, or for the tool to detect the wrong joint or point in the casing, and thus throw off all calculations and measurements accordingly. As the conventional well casing pipe has a length of some thirty feet, it will be seen that an error in the detection of one joint location, could cause a perforating gun or other tool to miss the stratum of interest completely.

Those skilled in the art are aware that the limitations of the prior art extend to other types of pipelines and the like, and are not limited only to generally vertical well bores. For example, the standard procedure for examining a cross-



country oil, gas, or other pipeline, is to "pig" the line, i.e., send a mechanical device (called a "pig") through the line, generally by pneumatic means. The "pig" may sense various information relating to the condition of the line, or other factors, which information may be stored within the device until it is recovered at some point in the line. However, any flaws or other problems in the line must be identified as to location, and the mechanical "pigs" used for such operations have no means of determining their position in the line. Rather, their location must be detected externally, by a worker stationed along the pipe or line as the "pig" travels through the line, and who logs the passage of the "pig" at various points along the line, relative to time. By knowing the time that any information was gathered in the pipe, and the time of passage of the "pig" at various points, the location of any anomalies may be indirectly determined.

However, it will be seen that it can be difficult to determine the precise location of various anomalies or other points of interest in such a pipeline, as the detection of the passage of the "pig" through the line, is determined at only a relatively few widely separated points along the line. Thus, when the record of the recovered "pig" is examined, it may not be possible to narrow the location of some point of interest in the line, to an area smaller than perhaps a few hundred feet of pipeline, or perhaps more.

Accordingly, a need will be seen for a system which positively identifies the location or depth of a well tool at various points within the well. The system comprises a plurality of passive or active radio frequency resonant devices, which are installed at several, or all, of the joints in the well casing. Each of the devices is preferably constructed or tuned to provide a unique individual signal. A well tool is provided which transmits a low power and/or directional signal on an appropriate frequency for reception by the devices, which then resonate to provide a responding signal to the well tool. The responding signal passes up the wire line to the well operator at the surface, who is able to determine precisely the location or depth of the well tool in the well. Alternatively, the information may be stored within the downhole tool, for downloading into a computer or other suitable reading device at the surface, after recovery of the tool.

A further need will be seen for a system which is capable of positively identifying the location of a tool which is passed through a pipeline or the like, and recording the location corresponding to the tool at various points in time as the tool passes through the pipeline. The system may utilize active or passive radio frequency resonant devices, with information being stored within the pipeline tool for later recovery when the tool is recovered from the line.

A discussion of the related art of which the present inventor is aware, and its differences and distinctions from the present invention, is provided below.

U.S. Pat. No. 4,572,293 issued on Feb. 25, 1986 to James G. Wilson et al., titled "Method Of Placing Magnetic Markers On Collarless Cased Wellbores," describes the magnetic polarizing of well casing by positioning one or more electromagnets within the casing, and activating the electromagnets to impart a permanent magnetic field at the location of the electromagnet(s) within the casing or pipe. The magnetically polarized area may be detected using a conventional magnetic reading casing collar locator. The Wilson et al. method does not provide any means of differentiating between magnetically marked spots, nor of precisely positioning the magnetically polarized areas at predetermined points in the casing. Moreover, Wilson et al. do not disclose any means of logging or determining the position of a device in a cross country or other fluid pipeline, as provided by the present method and apparatus.

U.S. Pat. No. 4,630,044 issued on Dec. 16, 1986 to Rudolf Polzer, titled "Programmable Inductively Coupled Transponder," describes a passive radio identification device (PRID) including a memory for modulating the response signal when triggered by an appropriate transmitter. Polzer describes the placement of the resonating transponder on a moving object, e.g., a railroad car, with the triggering transmitter having a stationary mounting. This configuration is precisely the opposite of the present invention, with its stationary responding devices and triggering transmitter being mounted within a moving well hole or pipeline "pigging" tool. Moreover, Polzer makes no suggestion of using his invention for determining depth or other characteristics in a well casing or other fluid pipeline, as provided by the present invention.

U.S. Pat. No. 4,808,925 issued on Feb. 28, 1989 to Gary K. Baird, titled "Three Magnet Casing Collar Locator," describes a magnetic device for detecting pipe or casing joints in a well. The device provides a specially shaped toroidal magnetic field, which magnetically affects the ferrometallic casing and casing joints. A detector associated with the device detects variations in the magnetic field as the field changes as it passes each casing joint. Baird makes no provision for detecting any differences in the joints. Rather, each joint appears essentially the same when detected, and the operator cannot determine precisely where in the casing the device is located. Each joint must be counted in order for the location to be determined, and no other information is provided by the Baird device. Baird does not disclose any means of logging or determining the precise location of a pigging tool in a cross country or other than vertical fluid pipeline, as provided by the present invention.

U.S. Pat. No. 5,279,366 issued on Jan. 18, 1994 to Patrick L. Scholes, titled "Method For Wireline Operation Depth Control In Cased Wells," describes the use of both magnetic and radioactive location markers in a well casing. The detector device is capable of detecting both high energy radiation (gamma rays) and magnetic anomalies, thus making it easier to confirm that: well depth logs using either system separately; are properly "tied in." The Scholes '366 U.S. Patent provides an excellent explanation of the problem of well depth control and logging, as well as the importance of a solution for the problem, in the Background of the Invention portion of the disclosure, as noted further above. However, Scholes does not provide any means of differentiating between different joints or other locations along the length of the casing, nor any radio frequency resonant means for doing so. Moreover, Scholes is silent regarding any form of logging or determining the position of a tool in other than a vertical line, whereas the present system may be applied to any fluid line in a generally vertical or other than vertical orientation.

U.S. Pat. No. 5,361,838 issued on Nov. 8, 1994 to Marion D. Kilgore, titled "Slick Line Casing And Tubing Joint Locator Apparatus And Associated Methods," describes a device which is usable with a slick line, i.e., a monofilament metal or other line which does not carry an electrical signal. The device relies upon an integral magnetic anomaly detector for detecting pipe or casing joints. When a joint is detected, the device drives a drag producing structure against the inner surface of the casing, with the drag registering as a momentary increase in tension on the line at the surface as the device passes the joint. Thus, the Kilgore device can only be used when being drawn upwardly through the pipe, and does not utilize any radio frequency resonance means. The Kilgore device is also unworkable in other than a generally vertical line, whereas the present system is operable in any fluid line, regardless of its orientation.

U.S. Pat. No. 5,457,447 issued on Oct. 10, 1995 to Sanjar Ghaem et al., titled "Portable Power Source And RF Tag Utilizing Same," describes a radio frequency (RF) device providing an interrogation signal and receiving a response from the interrogation signal. The device may be powered by any one or more of several electrical sources, including conventional battery power, solar or infrared cells, etc. However, Ghaem et al. are silent regarding a responding unit for their RF tag device. While the present invention makes use of an RF transmitter and receiver disposed within a well downhole tool, pipeline pigging tool, or the like, the present invention also makes use of inert or active resonant responding devices which are triggered by the RF transponder device of the well or pipeline tool, which resonant responding devices are not a part of the Ghaem et al. disclosure.

U.S. Pat. No. 5,497,140 issued on Mar. 5, 1996 to John R. Tuttle, titled "Electrically Powered Postage Stamp Or Mailing Or Shipping Label Operative With Radio Frequency (RF) Communication," describes a small and very thin radio receiver and transmitter, including a memory chip for modulating the transmitted signal to provide certain specific information, e.g., routing, etc. The Tuttle disclosure provides for a thin, flat battery for power of the device, and accordingly includes "sleep" and "wake" circuitry which is triggered by a transmission from another device. The present invention does not require any integral electrical power in the specific form of an electric battery, but resonates when power is received from a nearby transmitter. The present device may include active circuitry requiring electrical power, but the electrical power is generated by electrochemical means using the fluid within the well or pipe, as an electrolyte. The Tuttle device is not a resonant device.

U.S. Pat. No. 5,626,192 issued on May 6, 1997 to Michael L. Connell et al., titled "Coiled Tubing Joint Locator And Methods," describes a tube which is lowered into the well pipe string for locating pipe joints. The device includes a fluid passage formed generally axially therethrough, and an electromagnetic joint detector which senses the increased mass of each joint, according to the disclosure. When a joint is detected, a lateral valve is opened, which decreases the fluid flow resistance through the device and produces a pressure drop which is transmitted to the surface. The Connell et al. device can only sense each joint, and cannot detect any difference between different joints, whereas the present device may provide means for differentiating between different joints in the well casing or fluid pipeline.

U.S. Pat. No. 5,720,345 issued on Feb. 24, 1998 to Timothy M. Price et al., titled "Casing Joint Detector," describes a magnetic anomaly detector which detects the variations in magnetic flux across pipe or casing joints, as in other devices of the prior art discussed further above. The detector may also measure the distance traveled down the borehole, and correlate this distance with the number of joints passed. However, Price et al. make no provision for distinguishing between different casing or pipe joints, for determining precisely which joint is being passed at any given point. Also, as with other magnetic anomaly detectors, the device must be moving at some minimum velocity through the casing in order to generate the spike in electromagnetic energy for generating a detection signal. The present active or passive RF system is operable at any practicable velocity in vertical, horizontal, or otherwise oriented fluid pipelines of virtually any type, i.e., ferromagnetic or other material.

European Patent Publication No. 013,494 published on Jul. 23, 1980 to British Gas Corporation, titled "Measurement Of Velocity And/Or Distance," describes a device which produces a magnetic anomaly in the wall of a ferrometallic pipe, and then detects the anomaly as the device passes. The device may thus measure its velocity through the pipe, by measuring the time between the production of the magnetic anomaly and its detection by another part of the device, with the distance between the two components being known. As in other devices using magnetic principles or means discussed further above, the British Gas device cannot distinguish between different magnetic anomalies produced thereby, but can only count the total number of magnetic anomalies along the length of the pipe and provide a distance measurement based upon the distance between the magnetic anomaly producer and detector. No RF means, nor use in other than a generally vertical downhole, is disclosed in the British Gas Corporation patent publication.

European Patent Publication No. 412,535 published on May 11, 1994 to Michael L. Smith, titled "Tubing Collar Position Sensing Apparatus, And Associated Methods, For Use With A Snubbing Unit," describes a device for electromagnetically detecting tubing or joint collars for progressively opening and closing the blowout pressure seals of a blowout valve. Accordingly, there is no need, and no teaching, of any means for distinguishing between different joints along the length of the tube or pipe. Smith notes that the measurement of the pipes cannot be accomplished by odometer means alone, due to slight variations in pipe length and in the length of engaged threads at each coupling, to which problem the present invention responds. Moreover, the present system is adaptable to both generally vertical well holes, as well as generally horizontal or other orientation gas and other fluid lines.

European Patent Publication No. 651,132 published on May 3, 1995 to the Halliburton Company, titled "Method For Locating Tubular Joints In A Well," describes a device which applies lateral pressure to the walls of the pipe whenever a joint is detected. The increased drag of the device increases the tension on the line as the device is raised up the pipe, thus enabling the joints to be detected without requirement for an electrical connection between the device in the pipe and the surface. The device described in the '132 European Patent Publication is the same as that described in the '838 U.S. Patent, and discussed further above. The same differences and distinctions noted in the above discussion, are also seen to apply here.

Finally, European Patent Publication No. 730,083 published on Sep. 4, 1996 to the Halliburton Company, titled "Method And Apparatus For Use In Setting Barrier Member In Well," describes a device using conventional magnetic anomaly detection means for detecting pipe or casing joints, for positioning a barrier within the pipe or casing so that the barrier is not positioned on the joint. There is no need, and no teaching, for the device to distinguish between different joints, as all that is necessary for the Halliburton device is to determine that the barrier or seal will not be positioned directly on a joint.

None of the above inventions and patents, taken either singly or in combination, is seen to describe the instant invention as claimed.

## SUMMARY OF THE INVENTION

The present invention comprises a method and apparatus for determining position in a pipe or the like, for detecting pipe or casing joints in an oil, gas, or other drilled well or pipe, and for distinguishing between joints. The system includes a passive radio identification device (PRID), or alternatively an active device, installed at each pipe or casing joint, with a well or pipeline tool including a radio frequency transmitter and receiver. The transmitter of the tool provides a constant transmission signal, which is attenuated or directionally modified so as to be received only by an identification device at an immediately adjacent pipe or casing joint. When the device receives the transmission from the tool, the identification device circuit resonates to transmit a response, which is received by the tool receiver. The signal received by the receiver is then transmitted up the wireline between the tool and the surface, where it is processed. Alternatively, the tool may include means for recording the information received, with the information being downloaded from the tool upon retrieval of the tool at the surface or access point in a pipeline.

Information relating to each of the radio identification devices may be stored at the surface, with the operator being able to determine the location of the downhole tool at any time, and other characteristics which have been logged into the computer or information system, such as pipe or casing size, geological characteristics or stratum at any particular point as previously logged and entered into the system, depth of the well at that point, etc. Again, the present system is adaptable for use in generally horizontal fluid (oil, gas, water, etc.) pipelines as well as generally vertical downholes, and may be used in pipes of virtually any non-horizontal or non-vertical orientation as well. The present invention may also utilize identification devices which provide a distinct signal from one another, in order that the downhole tool is able to distinguish between each device, and therefore the joint with which any particular device is associated and the physical characteristics previously logged at that location.

While passive radio identification devices (PRIDs) which resonate when a specific frequency or frequencies are detected, may be used in the present invention, the present method and apparatus may also make use of active devices, i.e., devices requiring electrical power for operation. The present invention provides such electrical power in the form of an electrical battery, with two dissimilar metals being provided in the resonant device, or the resonant device and tool, with the fluid within the well or pipe serving as an electrolyte for the device.

Accordingly, it is a principal object of the invention to provide an improved method and apparatus for determining position in a pipe or the like, utilizing a radio frequency transmitter and receiver in a downhole or pipeline tool, with passive radio identification devices (PRIDs) or active devices located at each joint in the pipe or casing.

It is another object of the invention to provide an improved pipeline position determining method and apparatus which may include an information storage and retrieval system, such as a computer, at the surface or outside the pipeline, with the downhole or pipeline tool transmitting a signal to the system whenever a radio frequency identification device is detected.

Yet another object of the invention is to provide an improved pipeline position determining method and apparatus which may use a tool having recording means therein, for recording information detected during tool passage through the pipe, and for downloading the information from the tool recording means upon recovery of the tool.

It is a further object of the invention to provide an improved pipeline position determining method and apparatus which computer or other information system is programmed with various facts relating to each of the identification devices in the well or pipe, such as the stratum or geological characteristics at each identification device installed in the well, the pipe or casing diameter, distance between each of the identification devices in the pipe or casing string, etc.

An additional object of the invention is to provide an improved pipeline position determining method and apparatus which identification devices may be distinguished from one another, in order that the tool distinguishes the specific identification device with which it is communicating at any given location in the well or pipe.

Still another object of the invention is to provide an improved pipeline position determining method and apparatus which may utilize resilient seals disposed between each pipe or casing joint, for holding each of the identification devices in place.

Another object of the invention is to provide an improved pipeline position determining method and apparatus which may utilize active RF identification devices which draw electrical power from an electrochemical source provided by dissimilar metals in the RF device and/or tool, with the fluid within the well or pipe serving as an electrolyte.

It is an object of the invention to provide improved elements and arrangements thereof in an apparatus for the purposes described which is inexpensive, dependable and fully effective in accomplishing its intended purposes.

These and other objects of the present invention will become apparent upon review of the following specification and drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a broken away perspective view in section, of a section of well casing and joint including the installation of a radio identification device therein, and downhole tool including radio transceiver means therein for communicating with the device.

FIG. **2** is a schematic elevation view of a drilled well and casing, showing the general operation of one embodiment of the present invention and its communication with the surface and surface components associated with the invention.

FIG. **3** is a side perspective view in section of a pipeline coupling incorporating a radio frequency identification device in accordance with the present invention.

FIG. **4** is a perspective view of a radio frequency identification device and loop antenna for use with the present invention.

FIG. **5** is a perspective view of a sleeve installable in a pipe, including the identification device and loop of FIG. **4**.

FIG. **6** is an elevation view in broken away section of a pipe incorporating the present identification device and loop antenna, and including electrochemical energy generation means having dissimilar metals disposed in the loop and in the detection tool.

FIG. **7** is an elevation view similar to that of FIG. **6**, but having both dissimilar metals incorporated in the antenna loop.

Similar reference characters denote corresponding features consistently throughout the attached drawings.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention comprises a method and apparatus for determining position in a pipe or the like, for oil, gas, and other drilled wells having a jointed casing therein, and for cross country pipelines and other non-vertical gas, oil, water, and other fluid wells and pipelines. The present system provides for the determination of the precise location of a well or pipe tool within the casing or pipe, and associated characteristics of the well or pipe at the location of the tool.



FIG. **1** provides a broken away perspective view in section of a well casing or pipe **10** formed of a plurality of sections **12**, with each section **12** having a joint **14** therebetween comprising externally threaded connecting ends **16** with an internally threaded mating coupling sleeve **18** securing the two ends **16** together. Such joints **14** generally include at least a slight gap **20** between each connecting end **16** of the casing or pipe sections **12**, with a resilient O-ring **22** being placed in the gap **20** at the time of assembly of the joint **14**. A well downhole tool **24** is also shown in FIG. **1**, at the lower end of a wireline **26** which serves both to support the tool **24** within the casing **10** and also for electrical power and communication between the tool **24** and the surface, as shown in FIG. **2** and discussed further below.

The well tool **24** includes a radio frequency transmitter and receiver **28** therein, shown in broken lines in FIG. **1**. A radio frequency identification device **30** is installed at each of the coupling joints **14** of the pipe or casing string **10**, as by sealing, imbedding, or otherwise securing the device **30** within the resilient O-ring seal **22** at each joint **14**. The radio frequency identification device **30** may be in the form of a passive radio identification device (known as a "PRID"). Such PRIDs are conventional and are used for merchandise security in the retail industry, library security, etc., and generally comprise a solid state printed circuit which is configured to resonate upon receipt of radio frequency energy from a radio transmission of appropriate frequency and strength. Such devices do not require any additional power source, as the energy received from the transmission provides sufficient power for the device to respond with a weak and/or periodic reply transmission so long as it is receiving an appropriate transmission.

Alternatively, the responding device **30** may be in the form of an active device, requiring a separate source of electrical power (e.g., electrical storage battery or other electrical power means) . Such devices are also conventional, and may be configured to draw practically no electrical power until a radio frequency signal is received, whereupon they are electrically energized to produce a responding transmission.

The transceiver **28** enclosed within the well tool **24** is also conventional, and provides a radio frequency transmitted signal at the appropriate frequency to excite the PRID or active device **30** at any given joint **14** location. The transceiver **28** also includes a receiver tuned to receive the response from the PRID or active device **30**, which response is provided on a different frequency than the transmission frequency used by the transceiver **28** in order that the transmitted signal from the transceiver **28** does not interfere with the received signal from the PRID or active device **30**. The transmitter and antenna system of the transceiver **28** are preferably configured to provide a relatively weak signal which can only be detected and responded to by a PRID or active device **30** in relatively close proximity to the transceiver **28**, i.e., within a foot or so distant.

Alternatively, the antenna of the transceiver **28** may be configured to provide a highly directional signal, e.g., radially polarized or shielded to provide only a narrow radial transmission pattern, so the transmitted signal from the transceiver **28** radiates essentially horizontally from the transceiver **28** and well tool **24**. In this manner, the transceiver **28** will not trigger more than a single PRID or active device **30** at any point in the passage of the transceiver **28** through the casing pipe string **10**, and will be in very close proximity, e.g., within a few inches, of the exact depth of the responding PRID or active device **30**. Alternatively, the receiving antenna may provide only a narrow radial reception band for accuracy.

FIG. **2** provides a schematic elevation view of a drilled well **32** including a casing string **10** installed therein. The wireline **26** is shown extended from the conventional wireline head **34** (comprising a reel and/or other extension and retraction means for the wireline **26**, and conventional means for communicating electrical power and signals to and from the wireline **26** and thus to the well tool **24** at the lower end thereof), with the well tool **24** disposed at a specific joint **14***a* having a specific PRID or active device **30***a* installed therein. The radio frequency transmission of the transceiver **28** triggers a response from the adjacent PRID or active device **30***a,* causing the device **30***a* to resonate according to the transmitted frequency from the transceiver **28** and to transmit a responding signal on a different frequency. The different frequency of the responding device **30***a* transmission is detected by the receiver portion of the transceiver **28** in the well tool **24**, and is relayed back to the wireline head **34** for processing at the surface.

In many instances, the line **26** used to lower the tool **24** into the hole, and to withdraw the tool **24** from the hole, is a non-electric line. Accordingly, tools **24** used with such non-electric lines include recording means therein, with the data recorded by the recording means being downloaded to the remotely located computer and database after recovery of the tool from the hole or pipeline. Such data recording well tools are conventional, and are in use in the well and pipeline industry.

Normally, a drilled well is "logged" before casing is installed, in order to determine the exact depths of specific geological structures (e.g., impervious rock, oil and/or gas bearing strata, etc.). The information logged, as well as other information, such as the diameter or size of the casing, well name and/or number, depth of the well, etc., is entered into an information storage and retrieval system database, conventionally a computer **36** including appropriate programming for the application.

Thus, as the well downhole tool **24** passes each PRID or active device **30**, **30***a* at each joint **14**, **14***a* along the depth of the assembled well casing **10**, each device **30**, **30***a* responds with a signal which is relayed to the surface and ultimately to the computer **36**. By "counting" the number of PRIDs or active devices **30**, **30***a* which the well tool **24** has passed as it is lowered through the casing **10**, and comparing each consecutive PRID **30**, **30***a* with the corresponding data previously logged, the computer **36** can indicate the conditions at the location of the well downhole tool **24** in the well casing **10**. As an example, previously logged data may indicate that an oil bearing stratum is located between 12,000 and 12,200 feet below the surface. As the length of each of the casing sections **12** is known, the computer **36** need only divide the depth of the stratum by the length of the casing sections **12** to determine how many casing sections **12** (and thus how many joints **14**, with their associated PRIDs or active devices **30**) lie between the surface and the desired stratum. This allows the well casing **10** to be perforated accurately at the desired strata, assuring that good flow of the desired substance is obtained without any mixture of undesired substances (water, etc.).

It will be seen that each of the PRIDs or active devices **30**, **30***a* may be configured to provide a distinct and unique response, if desired, or at least several different responses may be provided for the plurality of PRIDs or active devices **30** used in the present invention. Such devices may be configured to provide different frequency responses, and/or modulation of the responses in some manner (amplitude, frequency, pulse) in order for each device to provide a distinct response.

In this manner, each PRID or active device **30**, **30***a,* etc. may be installed along the casing or pipe string **10** with each providing a different response. The different responses corresponding to each of the PRIDs are entered into the computer **36**. Thus, information is available as to the exact location of each independent PRID or active device **30**, **30***a,* etc. This may be important in the event that the system misses a response by one or more of the devices **30** installed along the pipe casing **10**. In such a situation, if all of the devices **30**, **30***a,* etc. provided identical response signals, the missing of e.g., two of the PRID or active device response signals would result in an error of about sixty feet in the determination of the depth of the well tool **24**. By providing each PRID with a distinct response signal, the computer **36** is able to determine the precise location of any given PRID or active device, even if a response signal was not received from one or more of the devices along the casing string **10**.

It will further be seen that it is not absolutely essential to provide a separate and distinct response signal for each of the PRIDs or active devices **30** along the string **10**. Provision for e.g., five different responses, with each identical response being installed five casing sections apart from one another in a repeating pattern, i.e., 1, 2, 3, 4, 5, 1, 2, 3, 4, 5, etc., would provide sufficient resolution for the location of the well tool **24** within the pipe or casing string **10**, even in the event that responses from one or two, or even four consecutive, PRIDs or active devices **30** were not received. Thus, an accurate representation of the location of the well tool **24** at each joint **14** may be provided by the present invention.

While the discussion to this point has been directed to the well of FIGS. **1** and **2**, it will be seen that the present invention is not limited only to use in generally vertical drilled wells and the like. The present method for determining position in a pipeline may be used in other pipeline environments, such as generally horizonal cross country gas, oil, or other fluid pipelines as desired, or in any pipeline orientation.

As an example of such use in a cross country pipeline, such lines are conventionally used for the transport of oil, gas, etc. between various points. It is necessary to inspect the interior of such lines from time to time, and this is conventionally accomplished by means of an automated tool, called a "pig," which is passed through the pipeline (generally "blown" through the line by increasing the pressure on one side of the pipeline relative to the tool). Such tools may include means of detecting various flaws within the pipeline, but may not include any means of determining their position in the line. Accordingly, a worker stationed along the pipeline logs the time when the "pig" passes, and travels to another point along the line where the process is repeated. When the "pig" is recovered from the pipeline, the data recorded by the conventional data recording means therein, is downloaded to some form of data recovery means (e.g., computer and database). The times at which any anomalies in the line were recorded by the data recording means in the "pig" are noted and compared to the times logged by the worker who noted the passage of the "pig" at various points along the line.

As can be seen, this provides only a very approximate idea of the position of the "pig" at any point where a pipeline anomaly was recorded, by interpolation of the times of passage at various points. Thus, the narrowing of the location where a more detailed inspection and/or repair is required, can be time consuming and costly. Moreover, such a system may result in the unnecessary replacement of a larger length of pipeline than is absolutely required, merely because the precise location of a flaw could not be accurately determined.

The present system provides a solution to the above problem, by means of installing a series of PRIDs or active radio frequency devices at various predetermined locations within the pipeline. Such PRIDs or active devices may be installed at joints in the pipeline, somewhat in the manner described above for the well casing or pipe, or in other areas of the pipeline as desired. The "pig" may include a transmitter and receiver similar to the conventional units which may be used in well downhole tools as described above, with the transmitter unit sending a continuous signal which is received by each of the radio frequency devices in turn as the "pig" travels through the pipeline. The devices sequentially provide responses as they are triggered by the transmitter in the "pig," with the receiver in the "pig" receiving the responding signals and the conventional recording means within the "pig" storing the location signals from the PRIDs or active devices, in a manner similar to that described above for well downhole tools having self contained recording means therein.

The data stored within the recording means, including the responding signals from the PRIDs or other active responding devices, is downloaded after the "pig" is recovered and is examined to determine if any flaws or other anomalies are present in the pipeline. If an anomaly is noted in the pipeline data, its location is easily determined relatively precisely by noting the PRID or active device signal at that location, or to either side of the location of the anomaly. Workers may then repair the problem as required, without need to spend substantial amounts of time and effort searching a relatively long length of pipeline for the problem, and/or replacing a large amount of the line in order to be sure that the problem was taken care of.

It may be desirable to provide a separate, relatively short section of pipe which incorporates a responding device therein, and which may be added to an existing pipeline or string as desired. Such a unit **38**, or "sub," is shown in section in FIG. **3** of the drawings. The "sub" unit **38** includes an internally threaded portion **40** at one end thereof and an externally threaded portion **42** at the end opposite the internally threaded portion **40**, thus allowing the sub unit **38** to be assembled between two sections of pipe or string to act as a joint therebetween. The sub unit **38** is particularly configured for the installation of a PRID or active device therein, by means of the internal groove or channel **44** provided circumferentially about the interior of the unit **38**. The channel **44** may include a PRID or other active radio frequency response device **30** imbedded therein, by means of a radio frequency transparent material **46** (e.g., resilient rubber or elastic material, plastic, etc.) installed within the groove or channel **44** for securing the PRID or active device **30** therein. In this manner, a series of such "sub" joints **38**, with each including a PRID or active device **30**, may be manufactured and installed in the field in a pipeline or well string, as desired. It will be noted that while threaded connecting ends **40** and **42** are illustrated for the sub joint **38** of FIG. **3**, that other connecting means (flanges, etc.) may be provided as desired and in accordance with the configuration of the line in which the sub joint is to be installed, without departing from the scope of the present invention.

As noted further above, the signal strength of the responding devices (PRIDs or active devices) need not be particularly high, as the receiver in the pipeline tool will always be located quite close to the passive or active responding device. However, additional signal strength may be desirable in certain circumstances, particularly in the case of PRIDs which do not have any supplemental electrical power but rely upon the electromagnetic energy provided by the transmitted signal. Accordingly, it may be desirable to provide some means of enhancing the signal received for such PRIDs. One such means is disclosed in FIG. **4**, where the PRID or active device **30** includes a circular loop antenna **48** installed therewith. The loop antenna **48** is configured to fit closely within a corresponding section or joint of the pipeline, casing, etc., as indicated by the section of loop antenna **48** shown installed in the section of sub joint **38** of FIG. **3**.

The loop antenna **48** also includes a wrap or encircling portion **50** surrounding the corresponding PRID or active device **30** installed therewith. The relatively large antenna loop **48** (compared to the relatively small antenna of the PRID or other device **30**, itself) is capable of receiving considerably greater signal strength from the transmitter as it passes that point in the pipe, as it completely surrounds the transmitter during the transmitter passage. The wrap of encircling antenna loop component **50** surrounding the PRID or active device **30**, thus re-radiates the received signal to the device **30**, thus providing a much stronger signal to the device **30** than would be the case without the supplementary loop antenna **48**.

In some instances, it may not be possible or convenient to install a PRID or other radio frequency responding device **30** at a joint location in a pipeline or pipe string. Accordingly, FIG. **5** illustrates a means of installing such a responding device **30** at some intermediate point in a pipeline or string, without need for specialized pipe components. FIG. **5** illustrates a sleeve **52** formed of radio frequency transparent material (plastic, etc.) which may be installed within a pipeline or string. The sleeve **52** includes a PRID or active responding device **30** therein, and may also include an antenna loop **48** therein as well. As in the case of the responding device **30** and antenna loop **48** of FIG. **4**, the antenna **48** may include a smaller loop **50** encircling the PRID or active device **30**, and providing the benefits noted further above. The responding device **30** and antenna loop **48** may be encapsulated into the wall of the plastic sleeve **52** during manufacture.

As noted herein, the responding devices **30** may be of two classes. One class comprises PRIDs, or passive radio identification devices, which do not require any additional form of electrical power. However, the other class of active responding devices requires some form of electrical power to provide a responding radio frequency transmission. Accordingly, such devices also require some form of electrical power source. Conventional electrical storage batteries may be provided for such active devices, if so desired, with long battery life being achieved by means of "sleep" circuits in such active devices to reduce electrical power requirements to practically nil when no radio signal is being received.

However, the present invention may also include another means of generating electrical power for such active responding devices, as illustrated in FIGS. **6** and **7**. FIGS. **6** and **7** show an O-ring, respectively **22***a* and **22***b,* installed within respective gaps **20***a* and **20***b* between pipe sections **12***a,* **12***a* and **12***b,* **12***b* and surrounded by a pipe coupling, respectively **14***a* and **14***b* in the two drawing Figures. FIG. **6** also illustrates a portion of a pipe or well tool **24***a* disposed within the pipe **12***a.* The groove or gap **20***a* of FIG. **6** includes a first electrochemically reactive metal component **54** therein, with the well or pipeline tool **24***a* including a second electrochemically reactive metal component **56** disposed to the outer surface thereof. The two metal components **54** and **56** are formed of dissimilar metals, e.g., copper and zinc, etc., having different electrolytic capacities.

The fluid **58** which flows through the pipeline or well bore casing **12***a,* normally provides some electrical conductivity and serves as an electrolyte for the dissimilar metals **54** and **56**. (The fluid **58** is not shown in the gap **20***a* in FIG. **6**, for clarity in the drawing Figure.) Accordingly, an electrical potential is developed between the two dissimilar metals **54** and **56**, which may be used to provide the relatively small amount of electrical power required for the operation of an active radio identification device (not shown in FIGS. **6** and **7**, but shown schematically in other drawing Figures). It is noted that while no electrical connections are shown in FIGS. **6** and **7**, such connections are conventional and well known in the art.

As an example, a first electrical connector may be connected between one terminal of the active responding device and the first dissimilar metal component **54**, with a mutual ground connector between the second terminal of the responding device and the second metal component **56** of the pipeline tool **24***a,* as by means of an electrical contact between the outer surf ace of the tool **24***a* and second terminal of the responding device. The electrolytic reaction of the dissimilar metals **54** and **56** and at least slightly electrolytically reactive fluid **58**, results in a current: flow between the two metals **54** and **56** and across the responding device, by means of the electrical contact between the tool **24***a* and second terminal of the responding device.

FIG. **7** illustrates a variation upon the assembly of FIG. **6**, with the two dissimilar metal components **54***a* and **56***a* both being installed within the wall of the pipe **12***b,* in the gap **20***b* formed therein at the assembly joint. The fluid **58** flowing through the pipeline (not shown in FIG. **7**, for clarity in the drawing Figure) flows around and past the two metal components **54***a* and **56***a,* thus serving as an electrolyte between the two. The two components **54***a* and **56***a* may be electrically connected to the terminals of an active radio identification device, as is conventionally done in the case of electrical storage battery power for such devices. However, the provision of the two electrochemically dissimilar metals **54***a* and **56***a* (or **54** and **56**, in FIG. **6**) serves to generate a certain amount of electrical energy, which is sufficient to supply the relatively small electrical energy needs of such active radio identification devices as used in the present invention.

In summary, the present method and apparatus for determining position in a pipeline provides a much needed system for easily and precisely determining the position of a well tool within a drilled oil, gas, or other well having a jointed well casing, or the position of a pipeline tool or "pig" within a pipeline. The present system is relatively simple and yet robust, with the PRID or active devices being used having great durability and reliability. The imbedding or sealing of each of the PRIDs or active devices within the resilient O-ring (rubber, Teflon; tm, etc.) located at each casing or pipe joint, provides further protection for the devices while simultaneously locating them precisely at each joint. The prior logging of the well hole characteristics, such as geological characteristics, depth of various strata of interest, well name and/or number, diameter of the casing to be used, etc., into a database, provides an operator at the surface with all information necessary to determine the appropriate action to take and the appropriate positioning of the tool for perforating the casing or other operations in the pipe.

It will be appreciated to those skilled in the art that the invention can be used in any type of pipe or casing, either vertically or horizontally oriented, and as found in refineries, chemical plants, oil and gas pipelines, underground water systems, or in any system where it is necessary to know the exact location of a tool or instrument being run through a pipe in any particular pipe system. The use of conventional self contained recording means within the well or pipeline tool, enables the present invention to be used with "slick-line" type tools as well, as no electrical or other communication is required through the line. Accordingly, the present system will provide well drillers and operators, pipeline operators, and others working with similar systems, with a much needed means of quickly, easily, and relatively inexpensively, determining the precise location of a well tool in a well and correlating that location with previously logged information for accurate operations.

It is to be understood that the present invention is not limited to the sole embodiment described above, but encompasses any and all embodiments within the scope of the following claims.

I claim:

**1**. A method for determining position in a fluid pipeline, comprising the following steps:

(a) providing a pipe tool including a radio frequency transmitter and receiver;

(b) further providing recording means for recording signals received by the receiver;

(c) further providing a plurality of radio identification devices for resonating and transmitting responses to the receiver of the radio frequency transmitter, when the radio identification devices receive a signal from the radio frequency transmitter;

(d) installing the radio identification devices in the pipeline, at predetermined intervals thereamong;

(e) passing the pipe tool through the pipeline;

(f) sequentially triggering a response from each of the radio identification devices within by means of the transmitter of the pipe tool, as the pipe tool with its transmitter passes each of the radio identification devices in the pipeline; and

(g) recording the responses of the radio identification devices using the recording means.

**2**. The method according to claim **1**, including the steps of:

(a) providing a plurality of joints along the pipeline; and

(b) installing one of the radio identification devices at each of the joints of the pipeline.

**3**. The method according to claim **2**, including the steps of:

(a) installing each of the radio identification devices in a resilient O-ring; and

(b) installing an O-ring having one of the radio identification devices therein, at each of the joints of the pipeline.

**4**. The method according to claim **1**, including the steps of:

(a) providing a closed antenna loop for each of the radio identification devices;

(b) encircling the radio identification device by wrapping a portion of the antenna loop therearound;

(c) dimensioning the antenna loop for fitting closely within the circumference of the pipeline; and

(d) installing the antenna loop and radio identification device encircled thereby, within the pipeline.

**5**. The method according to claim **1**, including the steps of:

(a) providing a plurality of radio frequency transparent sleeves configured for closely fitting within the pipeline;

(b) installing one of the radio identification devices within each of the sleeves; and

(c) installing each of the radio identification device equipped sleeves within the pipeline, at predetermined intervals thereamong.

**6**. The method according to claim **1**, including the steps of:

(a) providing a plurality of radio frequency transparent sleeves configured for closely fitting within the pipeline;

(b) further providing a closed antenna loop for each of the radio identification devices;

(c) dimensioning each antenna loop for fitting closely within the circumference of a corresponding one of the sleeves;

(d) encircling each of the radio identification devices with a corresponding antenna loop;

(e) installing one of the antenna loops and radio identification devices encircled thereby, within each of the sleeves; and

(f) installing the sleeves with their radio identification devices and antenna loops, at predetermined locations within the pipeline.

**7**. The method according to claim **1**, wherein the step of recording the responses of the radio identification devices using the recording means further includes the steps of:

(a) installing the recording means at a location remote from the pipe tool;

(b) providing a communication line between the recording means and the pipe tool; and

(c) transmitting the responses to the remotely located recording means by means of the communication line.

**8**. The method according to claim **1**, wherein the step of recording the responses of the radio identification devices using the recording means further includes the steps of:

(a) installing the recording means within the pipe tool;

(b) recovering the pipe tool from the pipeline; and

(c) downloading the responses from the recording means of the pipe tool.

**9**. The method according to claim **1**, including the step of providing battery electrical power for each of the radio identification devices.

**10**. The method according to claim **1**, including the steps of:

(a) providing first and second electrochemically reactive dissimilar metals within the pipeline, for each of the radio identification devices;

(b) electrically connecting the first and second dissimilar metals to the radio identification devices;

(c) separating the first and second dissimilar metals by providing flow of the fluid within the pipeline, therebetween; and

(d) utilizing electrolytic properties of the fluid for electrochemically generating electrical power for the radio identification devices by means of the first and second dissimilar metals electrically connected thereto, and the fluid disposed therebetween.

**11**. An apparatus for determining position in a fluid pipeline, comprising:

a pipe tool for passing through the pipeline, said pipe tool including a radio frequency transmitter and receiver;

recording means for recording signals received by said receiver; and

a plurality of radio identification devices disposed within the pipeline at predetermined intervals thereamong, for resonating and transmitting responses to said receiver of said radio frequency transmitter when said radio identification devices receive a signal from said radio frequency transmitter as said transmitter is passed through the pipeline.

**12**. The apparatus according to claim **11** wherein the pipeline includes a plurality of evenly spaced joints thereamong, including a resilient O-ring installed at each of said joints with each said O-ring including one of said radio identification devices disposed therein.

**13**. The apparatus according to claim **12**, including a closed circular antenna loop disposed within each said O-ring with each said antenna loop encircling one of said radio identification devices.

**14**. The apparatus according to claim **11** wherein the pipeline includes a plurality of joints thereamong, including a closed circular antenna loop disposed circumferentially within the pipeline at each of the joints with each said antenna loop encircling one of said radio identification devices.

**15**. The apparatus according to claim **11**, including a plurality of radio frequency transparent sleeves for installing in the pipeline at predetermined intervals and closely fitting within the pipeline, with each of said sleeves including one of said radio identification devices disposed therein.

**16**. The apparatus according to claim **15**, including a closed circular antenna loop disposed circumferentially within each of said sleeves with each said antenna loop encircling said one of said radio identification devices disposed within each of said sleeves.

**17**. The apparatus according to claim **11**, wherein said recording means comprises a data recording device externally disposed to the pipeline tool and to the pipeline, and including a communication line extending between the pipe tool and said recording means.

**18**. The apparatus according to claim **11**, wherein said recording means comprises a data recording device disposed within the pipeline tool, for downloading data from said data recording device after the pipe tool with said data recording device is recovered from the pipeline.

**19**. The apparatus according to claim **11**, wherein said radio identification devices are active devices requiring electrical power with each of said devices including an electrical battery therewith.

**20**. The apparatus according to claim **11**, wherein:

said radio identification devices are active devices requiring electrical power;

each of said radio identification devices includes a first and a second electrochemically reactive dissimilar metal electrically connected thereto; and

each said dissimilar metal being separated from one another by the fluid within the pipeline for electrochemically generating electrical power for said each of said radio identification devices by means of electrolytic properties of the fluid and corresponding electrochemical reactions with said first and said second dissimilar metal.

21. A method for determining a position of a tool in a fluid transmission line comprising:

providing a radio frequency transmitter and a radio frequency receiver on the tool;

providing a plurality of radio identification devices in the line at predetermined intervals therealong, each device configured to receive a first signal from the transmitter and to transmit a unique second signal responsive to reception of the first signal;

moving the tool in the line past the devices as the transmitter transmits the first signal to the devices and the receiver receives seconds from the devices; and

locating the tool in the line using the second signals.

22. The method of claim 21 wherein the line comprises a plurality of joints and the radio indentification devices are attached to the joints.

23. The method of claim 21 wherein the line comprises a well and the devices are located at known depths in the well.

24. The method of claim 21 further comprising providing a log of the line, providing a computer with data from the log, transmitting the second signals to the computer during the moving step, and using the computer to perform the locating step.

25. The method of claim 21 further comprising perforating the line using information from the locating step.

26. A method for determining a location of a tool in a well comprising:

providing a radio frequency transmitter and a radio frequency receiver on the tool;

providing a plurality of radio identification devices in the well at known depths configured to receive a first signal from the transmitter and to transmit a plurality of second signals to the receiver;

moving the tool through the well past the devices as the trnasmitter transmits the first signal and the receiver receives the second signals; and

using the second signals to determine the location of the tool in the well.

27. The method of claim 26 further comprising logging the well, and using data from the logging step to determine the known depths of the devices.

28. The method of claim 26 further comprising transmitting the second signals to a computer at a surface of the well and using the computer to perform the determining step.

29. The method of claim 26 further comprising perforating the well using information from the using step.

30. The method of claim 26 wherein the devices comprise passive or active radio identification device.

31. A method for determining a depth of a tool in a well comprising:

providing a plurality of radio indentification devices in the well, each device located at a known depth and configured to receive a first signal and to transmit a unique second signal responsive to reception of the first signal;

providing a transmitter on the tool configured to transmit the first signal and a receiver on the tool configured to receive second signals from the devices;

moving the tool in the well past the devices as the transmitter transmits the first signal and the receiver receives the second signals; and

transmitting the second signals to a surface of the well.

32. The method of claim 31 further comprising providing a fluid in the well and using the fluid to transit the first signal and to receive the second signals.

33. The method of claim 31 further comprising logging the well to obtain data and using the data to determine the known depth.

34. The method of claim 31 wherein the well comprises a fluid transmission line comprising a plurality of joints and the radio indentification devices are attached to the joints.

35. The method of claim 31 wherein the transmitting step is performed using a wire line.

36. The method of claim 31 further comprising providing a computer at the surface and the second signals are transmitted to the computer.

37. The method of claim 36 further comprising providing the computer with log data and using the data to quantify the depth.

38. An apparatus for determining position in a fluid line comprising:

a tool configured for moving through the line, the tool comprising a radio frequency transceiver; and

a plurality of radio identification devices in the line at known locations therealong, each device configured to receive a first signal from the transceiver and to transmit a unique second signal to the tranceiver as the tool passes in proximity to the device.

39. The apparatus of claim 38 wherein the line comprises a subterranean well.

40. The apparatus of claim 38 further comprising a computer configured to receive unique second signals from the devices and to quantify the position of the tool in the line.

41. The apparatus of claim 38 wherein the line comprises a plurality of couplings and the devices are on the couplings.

42. An apparatus for determining a location of a tool in a well comprising:

a radio frequency transmitter and a radio frequency receiver on the tool;

a plurality of radio identification devices in the well at known depths configured to receive a first signal from the transmitter and to transmit a plurality of second signals to the receiver as the tool is moved past the devices; and

a computer configured to receive the second signals and to ascertain the location of the tool.

43. The apparatus of claim 42 further comprising a well log data programmed into the computer.

44. The apparatus of claim 42 wherein the well comprises a fluid transmission line comprising a plurality of couplings, and the devices are attached to the couplings.

45. The apparatus of claim 42 further comprising a wire line attached to the tool for transmitting the second signals to a surface of the well.

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